Adsorption of Water on JSC-1A Lunar Simulant Samples

Remote sensing probes sent to the moon in the 1990s indicated that water may exist in areas such as the bottoms of deep, permanently shadowed craters at the lunar poles, buried under regolith. Water is of paramount importance for any lunar exploration and colonization project which would require self-sustainable systems. Therefore, investigating the interaction of water with lunar regolith is pertinent to future exploration. The lunar environment can be approximated in ultra-high vacuum systems such as those used in thermal desorption spectroscopy (TDS). Questions about water dissociation, surface wetting, degree of crystallization, details of water-ice transitions, and cluster formation kinetics can be addressed by TDS.

Lunar regolith specimens collected during the Apollo missions are still available though precious, so testing with simulant is required before applying to use lunar regolith samples. Hence, we used for these studies JSC-1a, mostly an aluminosilicate glass and basaltic material containing substantial amounts of plagioclase, some olivine and traces of other minerals.

Objectives of this project include: 1) Manufacturing samples using as little raw material as possible, allowing the use of surface chemistry and kinetics tools to determine the feasibility of parallel studies on regolith, and 2) Characterizing the adsorption kinetics of water on the regolith simulant. This has implications for the probability of finding water on the moon and, if present, for recovery techniques.

For condensed water films, complex TDS data were obtained containing multiple features, which are related to subtle rearrangements of the water adlayer. Results from JSC-1a TDS studies indicate: 1) Water dissociation on JSC-1a at low exposures, with features detected at temperatures as high as 450 K and 2) The formation of 3D water clusters and a rather porous condensed water film. It appears plausible that the sub-μm sized particles act as nucleation centers.

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Water on the Moon

- Possibly in Deep Permanently Shadowed Craters

- Adsorbed

  Multiple layers of H_2O

- Chemi/Physisorbed

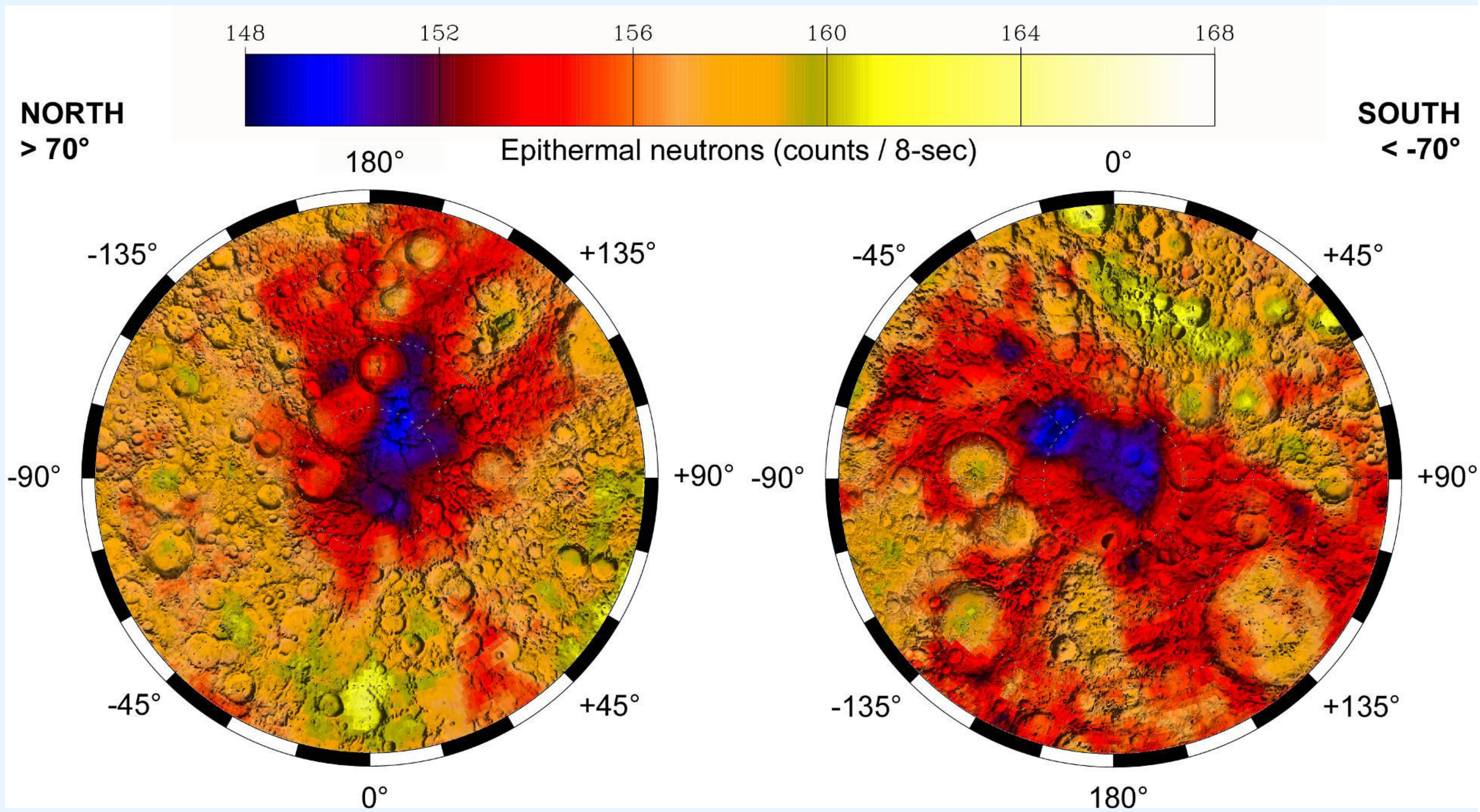
  Dipole interaction $\quad O_{(X-1)}MO \text{ --- } HOH$

  Coordinated $\quad O_xM — OH_2$

- Reacted

  Metals (Metal Oxides) $\quad CaO + H_2O \rightarrow Ca(OH)_2$

Lunar Hydrogen Map



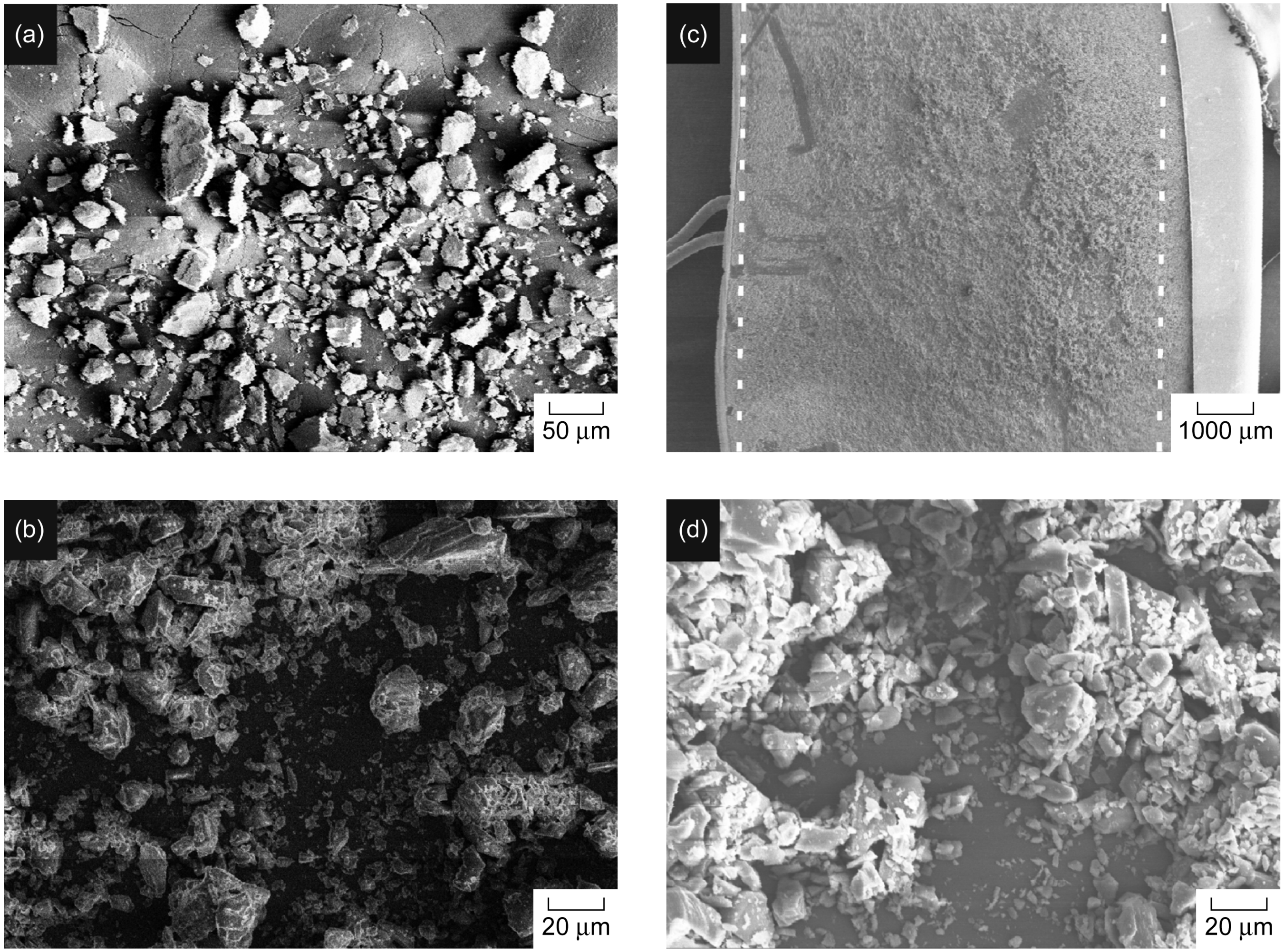
Hydrogen as …? Implanted H?? Water???

If Water Exists on the Moon, Then How?

- Use JSC-1A Simulant (fine powder)
- Clean Surface (UHV)
- Apply a Few Mono-Layers Water
  (UHV – Very Low Temp)
- Follow Desorption (TDS)
- Correlate with Other Studies of Terrestrial Systems

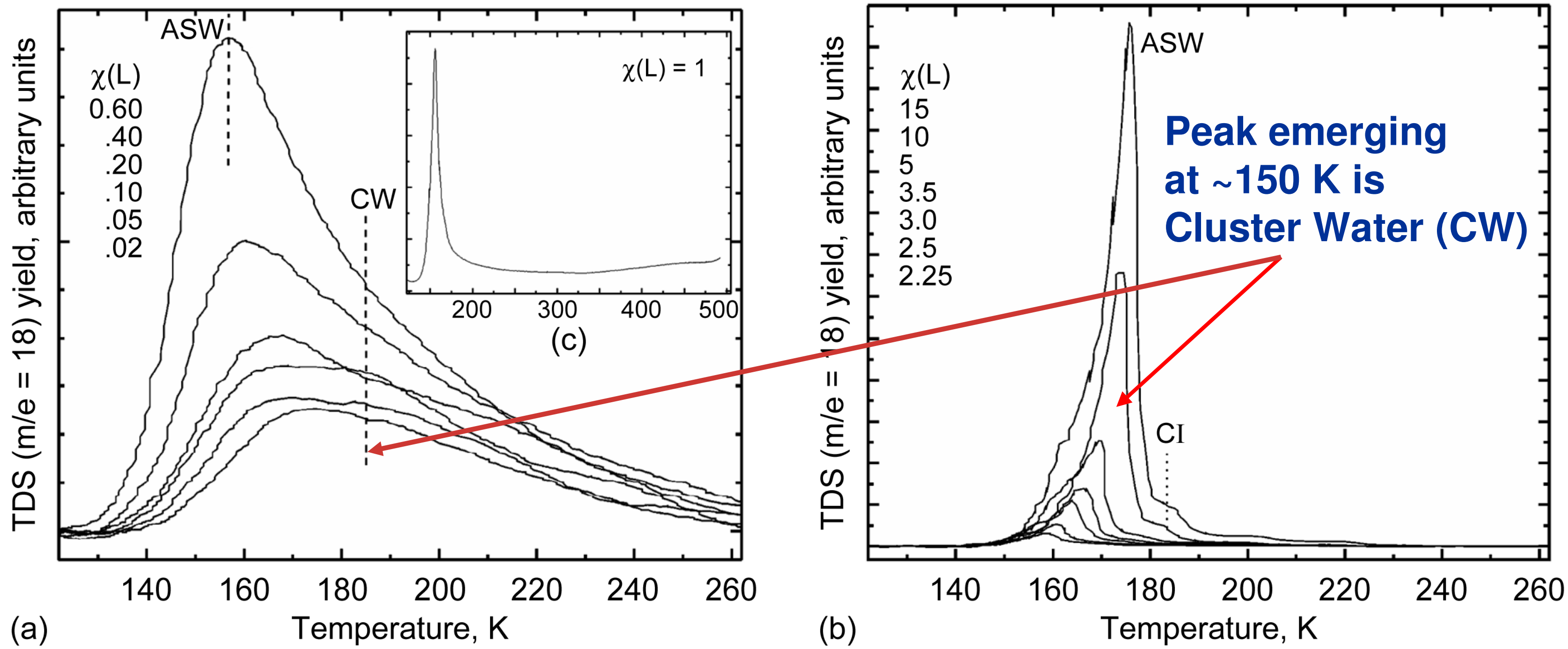
TDS is Thermal Desorption Spectroscopy
(Heat Sample, follow Mass Spectrometry)

The JSC-1A Mounted Sample



Images Before (left) and After (right) show No Sintering.

Examination of TDS from Si Mounting Substrate



Single well defined peak at Low Exposures (Water adsorbed at 90 K:

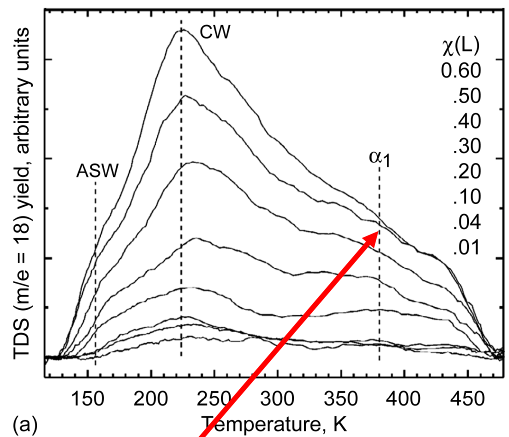
1) independent of exposure

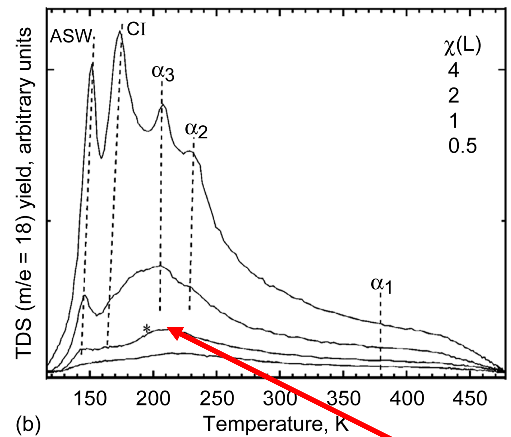
2) first order kinetics

=> NO Dissociation on substrate

ASW = Amorphous Solid Water

Examination of TDS from JSC-1A on Substrate





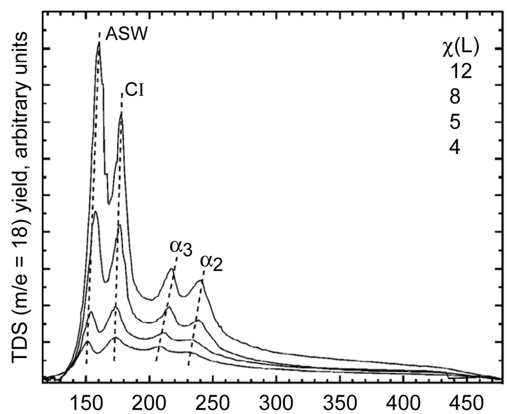
ASW = Amorphous Solid Water

CW = Cluster Water

CI = Crystalline Ice

$\alpha_1 = 2OH_{Ads} \rightarrow H_2O_g + O_{Ads}$

α_2 and α_3 = OH-H_2O Clusters



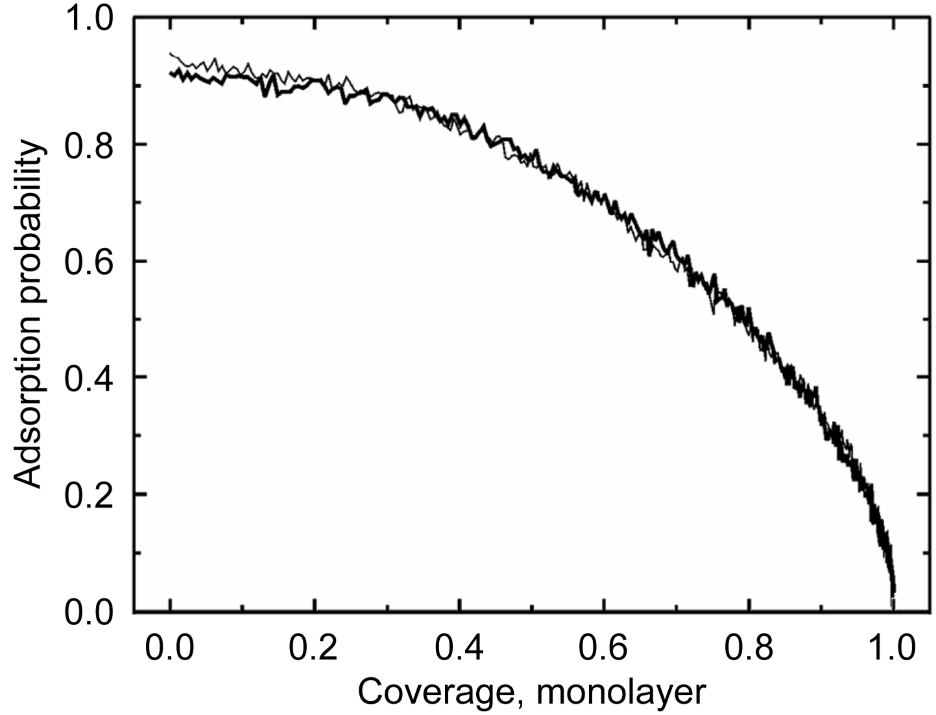
Note: 1L is ~ 1Monolayer
this relationship in NOT linear
(4L ~ 6 ML and 12L ~ 50 ML)

Water Adsorbed at 90 K

Probability of Adsorption on JSC-1A at low Temperature

JSC-1A has a 92% probability of adsorbing water at
1) Low Temp and
2) low surface coverages.

These caveats are realistic for Lunar Conditions!



Integrated Absorption Isotherm
(Adsorption Probablility vs Coverage)
Adsorption at 153 K and 1×10^{-12} bar

Concluding Remarks

- Water can realistically adsorb on JSC-1A under Lunar Conditions
- Water adsorbs to JSC-1A by Chemical pathway

$$2OH_{Ads} \leftarrow H_2O_g + O_{Ads}$$

- These studies should be applied to Lunar Regolith

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  of the Exploration Technology Development Program

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Water + Alkane Coadsorption

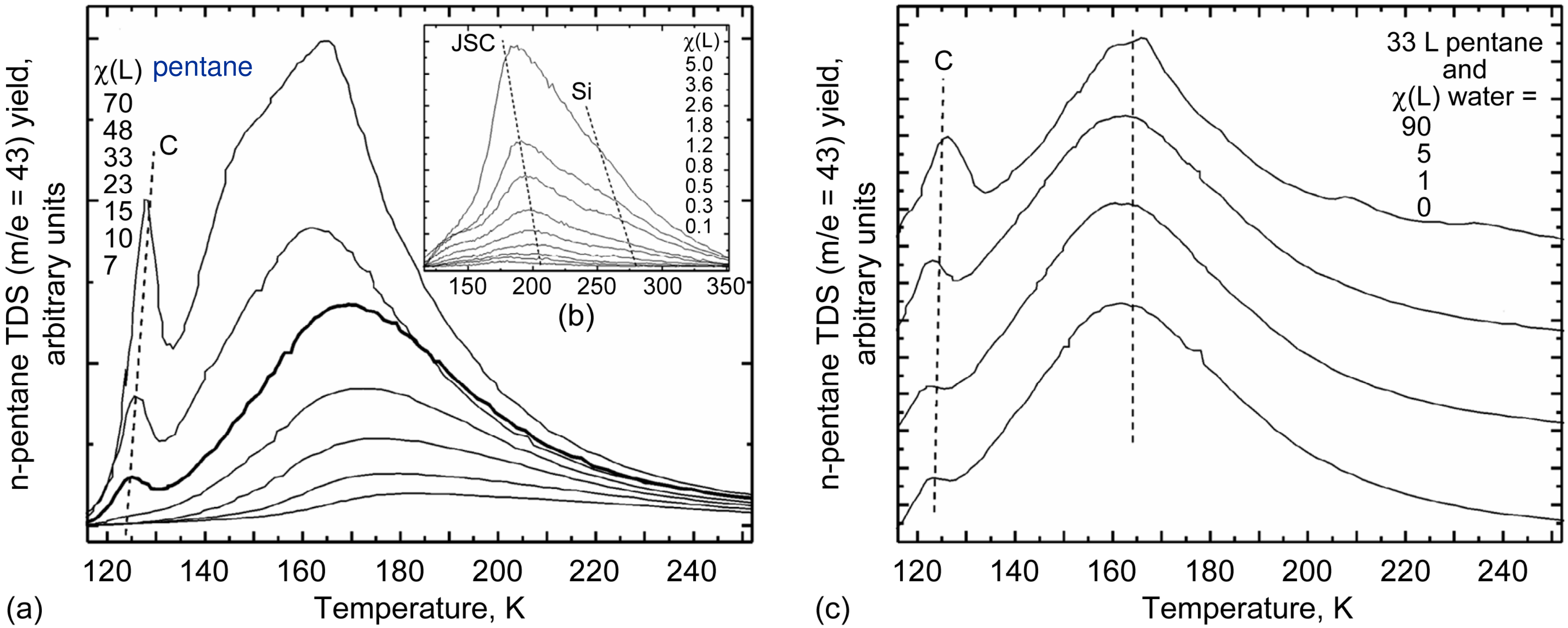

Figure 5.—(a) and (b) n-pentane thermal desorption spectroscopy (TDS) data obtained for the JSC-1a at large and small (inset) exposures. (c) Co-adsorption of n-pentane and water on JSC-1a/silica. The pentane exposure has been kept constant (33 L) and the water exposure varied, as indicated (T_{ads} = 90 K).

Coadsorption with inert (non polar) gas yields information about growth morphology of Ice Layers